CITRUS HERBICIDE MITIGATION PRACTICES:

DEMONSTRATION AND EVALUATION

Final Report for Contracts 01-0173 and 01-0176
Submitted to
The California Department of Pesticide Regulation

June 30, 2002

by

Neil O'Connell, Farm Advisor
Tulare County
Visalia, CA

Fuhan Liu, Postgraduate Researcher
Kearney Agricultural Center
University of California
Parlier, CA

California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring Branch
Environmental Hazards Assessment Program
1001 I Street, Sacramento, California 95814-3510

EH03-01

SUMMARY

Simazine loss from soil to surface runoff water produce both a decrease in the effectiveness of the soil chemical treatment and a water quality hazard in receiving waters. Simazine has been found in 30% of wells sampled in Fresno and Tulare counties, California and some contamination has been attributed to simazine use in citrus orchards. Contamination of receiving water from herbicides could put important weed control tools at risk and potentially increase risks to human health. In order to better understand the off-site movement of herbicides, studies were conducted in citrus orchards to evaluate weed control efficacy under selected weed management practices and to measure selected management practices for mitigating preemergent herbicide movement in rainfall runoff from citrus orchard middles. The results showed weed management practices that avoid broadcast application of preemergent herbicides during the rainy season were as effective as the standard rate at 2.0 lb ai /acre for weed control by using spray application to the entire orchard floor. The most common weed species included: spotted spurge, common groundsel, horseweed, annual sowthistle, and purple cudweed. Common groundsel is found to be resistant to preemergence application. Modifying how preemergence herbicides are used to control weeds is becoming increasingly important to protect the environment and to continue use of these important weed control tools. Runoff water data showed that the first runoff events following application of simazine produced peak concentrations. Data also showed that shallow mechanical incorporation and surfactant application did not consistently reduce mean concentration of simazine in runoff water. However, shallow mechanical incorporation and surfactant application reduced mass loss in runoff water. Soil simazine concentration was much higher in the middle than in the furrow after post-rainfall. Plots with shallow mechanical incorporation had higher recovered simazine than the plots without mechanical incorporation.

I. INTRODUCTION

The two California counties with the largest number of confirmed premeergent herbicide detections in well water are Fresno and Tulare. One mechanism of preemergent herbicide movement to ground water is through surface water runoff to dry wells or other drainage structures. Surface runoff from soil often carries pesticides that can have adverse effects on water quality. Surface water resources which receive drainage from intensively farmed agricultural production areas are likely to contain higher levels of pesticides, particularly at times related to recent use of pesticide (Barker and Mickelson, 1994; Goolsby et al., 1993). Larger amount of winter rain occur in the eastern San Joaquin Valley of California and they are believed to be associated with pesticide contamination of receiving waters (Lee, 1983; Pickett et al, 1990). Concentrations of simazine, diuron, and bromacil ranging up to 1100 ppb have been detected in rainfall runoff water entering dry wells in and around citrus orchards (Braun and Hawkins, 1991). This direct transport mechanism is most important in impermeable hardpan or compacted soils.

In experimental plots, shallow mechanical incorporation (using a small rototiller) has been shown to be effective in mitigating herbicide movement off-site in simulated rainfall runoff from middles of citrus orchards (Troiano and Garretson, 1998). However, the effect of shallow mechanical incorporation using more commonly available implements in production agriculture under actual rainfall conditions has not been demonstrated. In addition, many citrus growers are reluctant to disturb soil in orchard middles so that additional alternatives for mitigating herbicide movement off-site from citrus orchard middles are desireable.

II. OBJECTIVE

Table 1 was the selected treatments. The overall purpose of this project was to (1) demonstrate and (2) compare selected management practices for mitigating preemergent herbicide movement in rainfall runoff from citrus orchard middles. All data could be used to educate growers on different aspects of citrus orchard floor management practices, especially as they relate to weed control and frost protection. The study consisted of three experiments with the following objectives, respectively:

Experiment 1. Evaluate weed control efficacy under selected weed management practices that avoid broadcast application of preemergent herbicides during the rainy season when runoff potential is high. Weed population densities under such management regimes were compared to a control consisting of a typical citrus preemergent weed control program. The results could be used in citrus grower outreach and education programs to demonstrate the effect of ground water protection management strategies on weed control in citrus. All data could be used to educate growers on different aspects of citrus orchard floor management practices, especially as they relate to weed control and frost protection.

Experiment 2. Evaluate the potential frost protection risk from cover cropping by comparing canopy temperatures in cover cropped citrus to a control consisting of a typical citrus preemergent weed control program. The results were be used to determine if there was a statistically significant difference in canopy temperatures under cover crop vs. bare ground citrus orchard floor management practices.

Experiment 3. Evaluate the effect of different methods of herbicide incorporation on mass export of preemergent herbicide from citrus orchard middles in post-application rain runoff. Because simazine is the most widely detected herbicide in ground water of citrus producing areas in Tulare County, simazine will be the representative preemergent herbicide analyzed. The relative effect of different treatments will, however, be general for common preemergent citrus herbicides as they display very similar runoff behavior (Spurlock et al., 1997). The results could be used to document the effect of different incorporation strategies on off-site movement of simazine from citrus orchard middles relative to rainfall incorporation.

Table 1. Treatments for experiment 1-3

Exp	Treatment	Response variable
1	1. Fall and Winter: Glophate herbicide(1lb ai /acre) Spring: chemigation, thiazopyr (@ 1 lb ai/acre)	Weed counts
1	2. Fall: contact herbicide (simazine + diuron applied in the middle @ 2 lb ai/acre) Spring: chemigation, simazine + diuron (@ 1 lb ai/acre)	Weed counts Simazine: soil background, application deposition, runoff water, post-runoff soil; runoff water volume

1	3. Move emitters under skirt, glophate applied in the middle (@1 lb ai/acre)	Weed counts
2	4. Cover crop: filter strip, annual cover 4a: cover crop whole middle 4b: cover crop 10% of the middle 4c: bare soil	Canopy temperature, runoff water volume, simazine and diuron concentration
3	5. Fall: simazine + diuron @ 2 lb ai/acre) Shallow discing and ring roller incorporation	Simazine: soil background, application deposition, runoff water, post-runoff soil; runoff water volume
3	6. Fall: simazine + diuron @ 2 lb ai/acre) Schmeiser ring roller incorporation	"
3	7. Fall: simazine + diuron (@ 2 lb ai/acre) + surfactant	"
1-3 Control	8. Fall: simazine + diuron (@ 2 lb ai/acre), rainfall incorporation	" Weed counts, canopy temperature
	9. No any herbicide application and other practices	Weed counts

III. STUDY DESIGN

This study was conducted in a mature citrus grove located in runoff prone soils in Tulare County. These soils are classified according to the statistical clustering/profiling method of Troiano et al. (1994, 1997). The treatments listed in Table 1 were to be studied using a randomized complete block design.

The plots (experimental units) for treatments 1 and 2 were 2 rows wide x 10 trees long . The plots for treatments 3-8, 9 were 1 row x 10 trees long. All treatments were replicated six times.

Experiment 1

Treatments 1-3, 8 , 9
Glyphosate were applied during late fall/winter on as-needed basis using a $C0_2$ pressurized back pack sprayer. Weed control in spring consisted of a chemigation application of thiazopyr (treatment 1), chemigation application of simazine and diuron (treatment 2), and spot treatment with glyphosate (treatment 3). Representative weed counts were conducted in April by counting all emerged weeds by sampling an area of 45 m^2.
The response variable weed density was analyzed using analysis of variance (ANOVA). Mean separation between treatments were determined using Fisher's Protected Least Significant Difference procedure.

Experiment 2

Treatment 4, 8
A cover crop mix of annual medics, subterranean clover, and annual grasses were planted in treatment 1 orchard middles. A cover crop mixture of sheep fescue and hard fescue were planted in the bottom 10% of the irrigation run in treatment 2 orchard middles. A filter strip mixture of

sheep fescue and hard fescue were also planted adjacent to the orchards. The cover crop was planted in November 2000 using a cover crop grain drill. The collection buckets with temporary diversion panels were placed at the end of each plot to collect runoff. Hobo Temp sensors were set at 6 feet for monitoring canopy temperature.

<u>Experiment 3</u>

Treatments 2, 5-8
All bucket auger soil core sampling were conducted in accordance with EHAP SOP FSSO 002.00, all surface soil sampling were conducted in accordance with EHAP SOP FSSO 003.00, and all runoff water sampling were conducted in accordance with EHAP SOP FSWA 008.00. The soil and water sampling were discussed below.

Background soil samples

Two background soil samples were collected from each plot before simazine application: one taken from the row middle and one from the plot furrows. The row middle soil samples were a composite of three individual randomly located 10 cm cores. The plot furrow soil samples were a composite of four soil cores, two taken from each furrow within the plot.

Herbicide deposition sampling

The herbicide were broadcast applied using a $C0_2$ pressurized ground sprayer at a nominal rate of 20 gallons acre^{-1} on January 6, 2000. Each treatment included application of simazine and diuron at 2 lbs a.i. acre^{-1}. Herbicide deposition rates were measured in each plot using three randomly positioned kimbies located in row middles.

Runoff collection

Runoff water from the rainfall events was collected immediately past the downstream end of the plot furrows using a runoff sampler. One runoff sample was collected from the first container and two 1 L samples from the secondary container per plot per runoff event. The samples were stored (unfiltered) refrigerated at 4C until analysis. Total runoff volume were measured by the runoff sampler. Five significant runoff events were sampled.

Post- rainfall soil samples

Six post-rainfall soil samples were collected from each plot on February 28, 2000: three taken from the row middle and three from the plot furrows. Each row middle soil sample was a composite of two individual 10 cm cores. The plot furrow soil sample was a composite of two soil cores, one taken from each furrow at the locations specified

IV. CHEMICAL ANALYSIS / QUALITY CONTROL

Samples were analyzed for simazine by California Food and Agriculture Analytical Chemistry Laboratory (CDFA) in Sacramento using the ELISA immuno-assay method (method 62.7, copy attached); the detection limit in soil is 15 Pg kg-1 , while that for water is 0.5 ug L-'. The soil ELISA QA/QC procedures consisted of a matrix blank plus two matrix spikes to be included with each extraction set. Water samples were stored refrigerated (4C) and soil samples were stored frozen for a period of no longer than 16 weeks (see attached simazine storage stability study data sheet).

V. RESULTS AND DISCUSSION

Experiment 1

Weed density with herbicide treatment had significantly fewer weeds when contrasted to the untreated control (Table 2). The most common weed species included: spotted spurge, common groundsel, horseweed, annual sowthistle, and purple cudweed. However, spotted spurge and common groundsel consisted of almost 90% of the weeds found in the treated plots. Common groundsel is found to be resistant to herbicide application.

Table 2. Total weed density of each treatment

Treatment # †	Weed density (# /45 cm^2)
1	4 b ‡
2	2 b
3	5 b
8	2 b
9	9 a

† Treatment numbers refer to Table 1
‡ Means within a column followed by the same letter are not significantly different to an LSD test at the 0.05 level.

The results showed weed management practices that avoid broadcast application of preemergent herbicides during the rainy season were as effective as the standard rate at 2.0 lb ai /acre for weed control by using spray application to the entire orchard floor. Modifying how preemergence herbicides are used to control weeds is becoming increasingly important to protect the environment and to continue use of these important weed control tools.

Experiment 2

We had no rain following cover crop planting for about two months, so cover crop establishment has been minimal. We haven't attempted to take any measurements of runoff because of this. In regard to runoff the only rain we had early was in October, then nothing until January. We have had between 1-2 inches from Jan 13 to Jan 29.
Though we could record canopy temperatures, these data are not very useful due to the poor stand of the cover crop.

Experiment 3

Simazine concentration and mass that moved off the plots in runoff

Runoff water samples were collected for five significant runoff events. Simazine runoff concentration of selected treatments (trt 2, 5, 6, 7, and 8) related to the runoff events were showed in Figure 1 & 2. In general, the first storm runoff event following simazine application produced peak concentrations if heavy rainfall occurred immediately. Then the concentrations in runoff water decreased rapidly. The amount of simazine available for runoff is greatest at the start of the runoff events. The data showed that treatment 2 had least simazine concentration among the selected treatments. Mechanical incorporation (treatment 5 and treatment 6) and surfactant application (treatment 7) significantly reduced the simazine concentration for the first runoff event sampled from the first container compared to control (treatment 8); however, no effects were found for the runoff events sampled from the secondary container. Mechanical incorporations did not consistently reduce mean concentration of simazine in runoff water. Figure 3 showed simazine total runoff loss for each treatment. For all treatments, the recovered simazine in runoff was less that 5% of applied simazine. Runoff water did not play a significant rule in simazine mass loss. Mechanical incorporations (treatment 5 and 6) and treatment 7 with surfactant application had less mass loss compared to treatment 8.

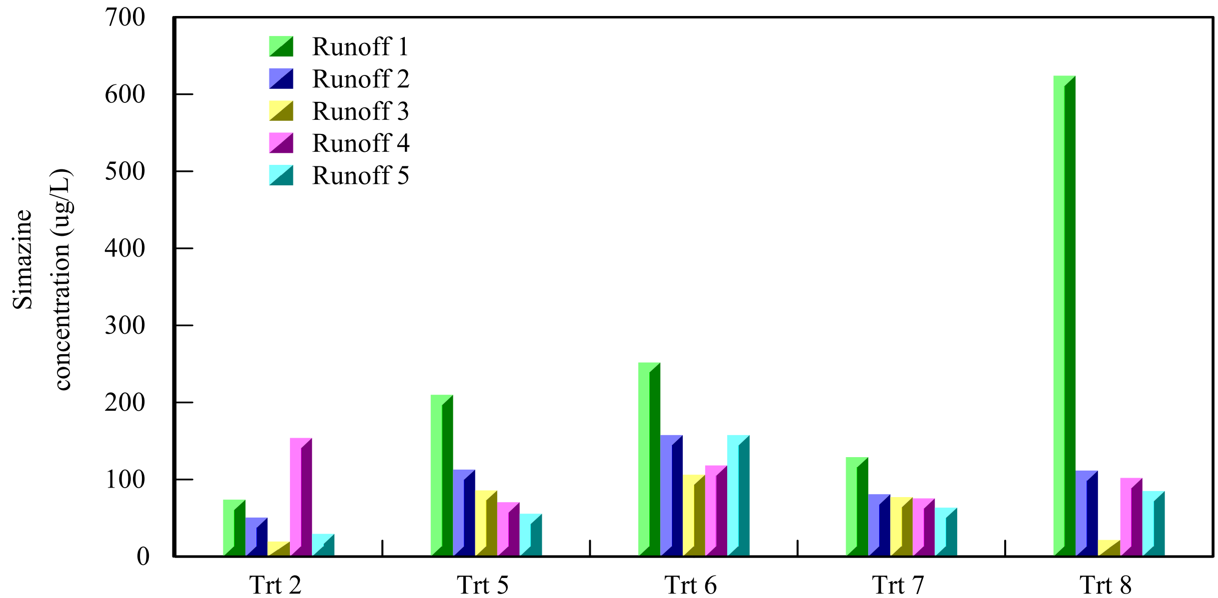

Figure 1. Simazine runoff concentration of different treatments related to the runoff events. The samples were taken from the first container. Treatment numbers along the x-axis refer to Table 1.

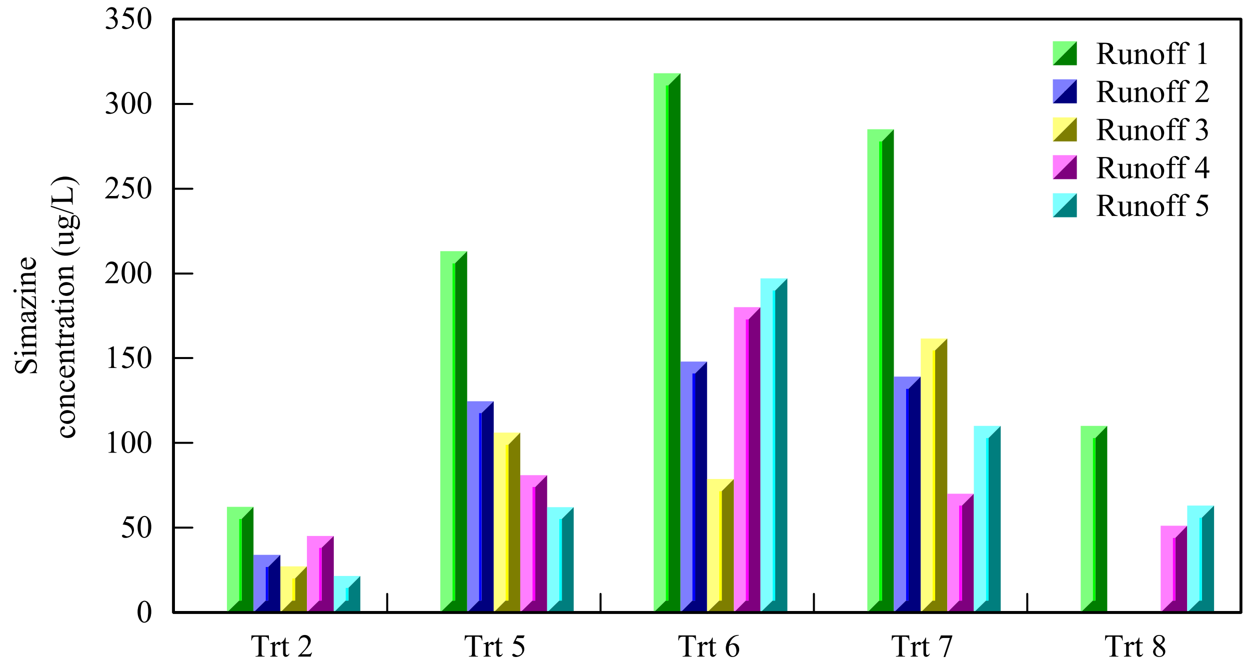

Figure 2. Simazine runoff concentration of different treatments related to the runoff events. The samples were taken from the secondary container. Treatment numbers along the x-axis refer to Table 1.

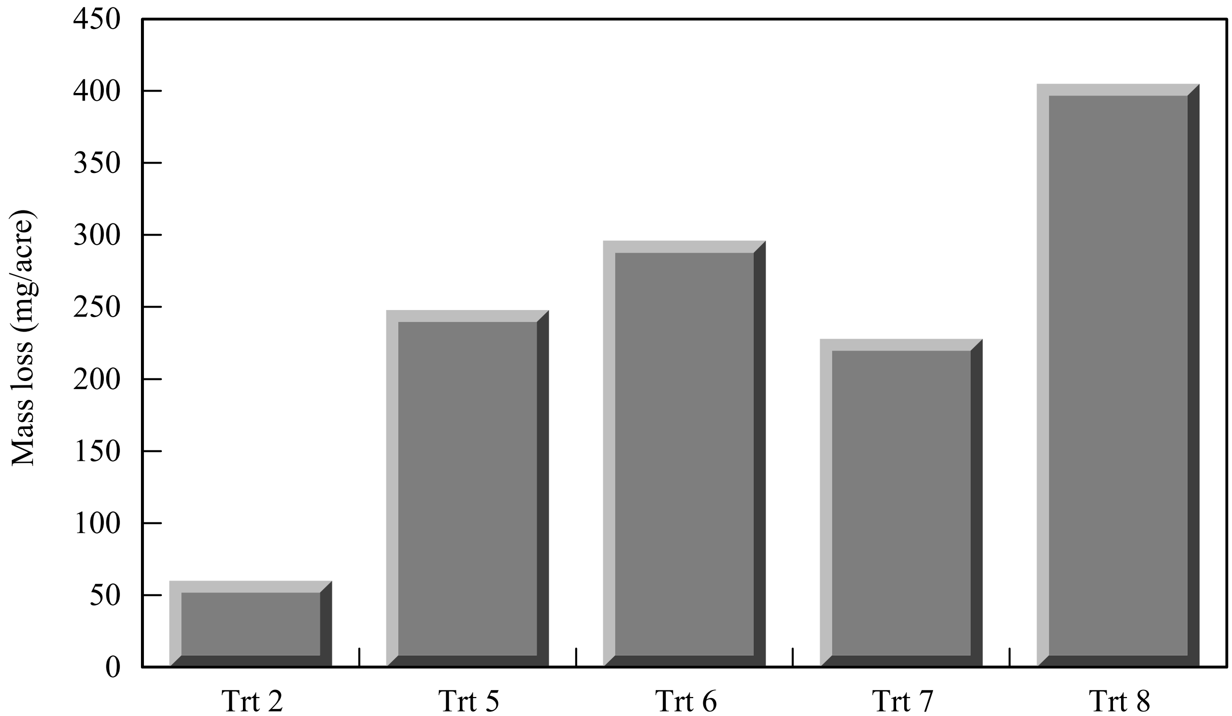

Figure 3. Total simazine mass loss in runoff water for each treatment. Treatment numbers along the x-axis refer to Table 1.

Simazine concentration and recovery in soil

Simazine was applied in the treated plots on January 06, 2000. The post-rainfall soil samples taken from furrow and middle of the plots were taken on Febuary 28, 2000. Figure 4 showed the simazine concentration along the runoff path in the plots. Runoff water was flowing from position 1 to position 2. Figure 5 was the mean concentration of the three sampling positions. Soil simazine concentration was much higher in the middle of plots. Recovered simazine from soil ranged from 78% to 25% for different treatments (Figure 6). Plots with shallow mechanical incorporation had higher recovered simazine that the plots without mechanical incorporation. Plots with shallow discing and roller incorporation had the highest recovery.

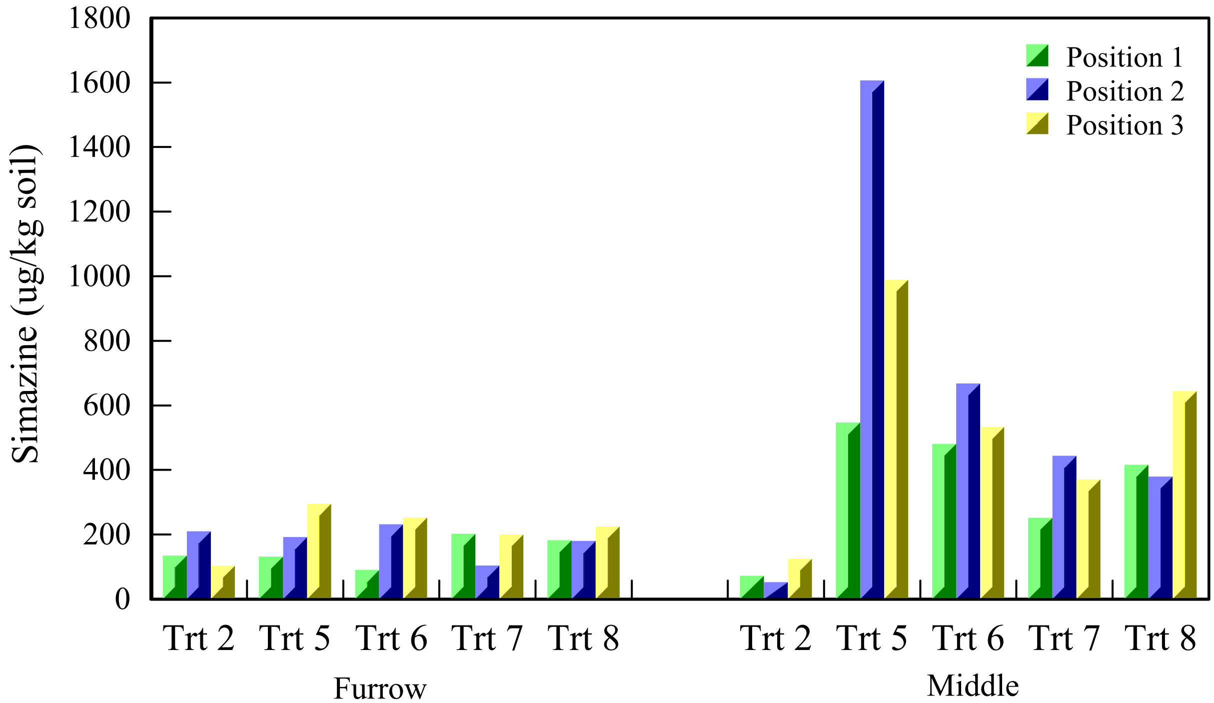

Figure 4. Soil simazine concentration at each sampling position specified. Runoff path was from position 1 to position 3. Treatment numbers along the x-axis refer to Table 1.

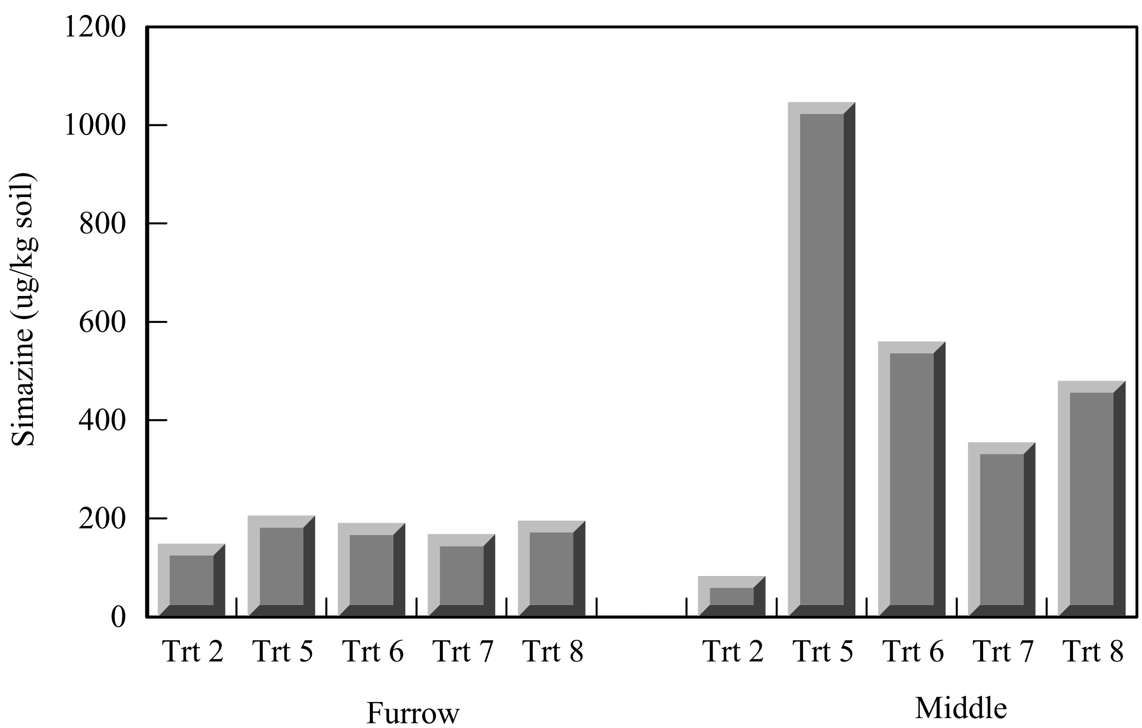

Figure 5. Mean soil simazine concentration.

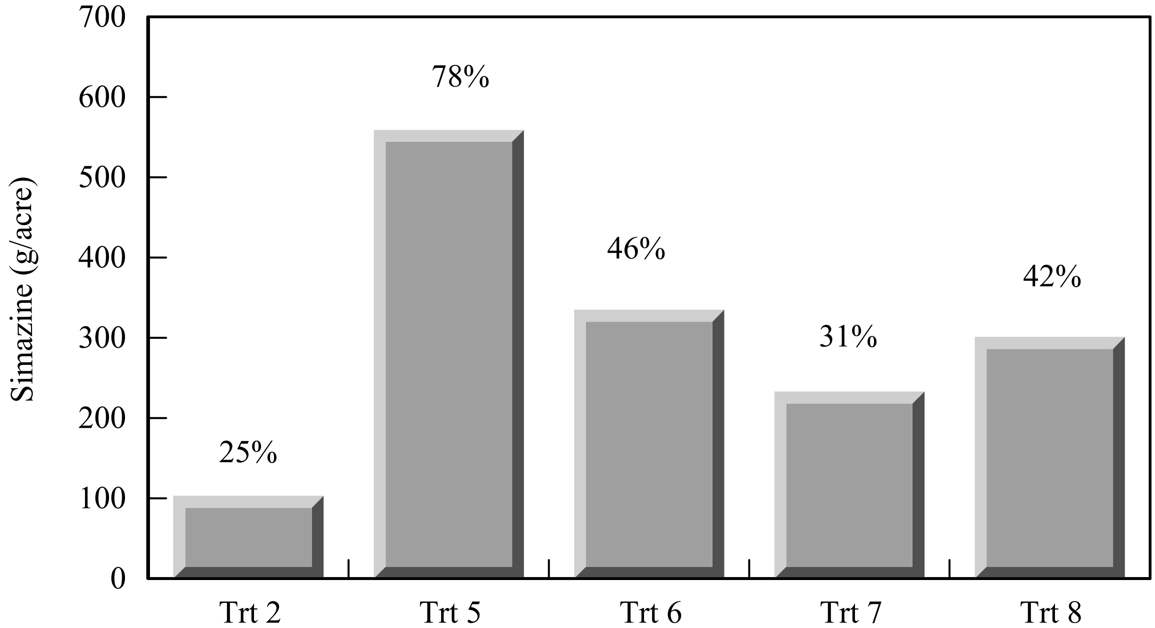

Figure 6. Recovered simazine from 0 – 15 cm soil depth. The treatment numbers along the x-axis refer to Table 1. The numbers on the top of each bar was the recovered percentage of applied simazine.

VII. REFERENCES

Barker J.L., and S.K. Mickelson. 1994. Application technology and best management practices for minimizing herbicide runoff. Weed Technology, 8:862-869.

Braun, A.L. and L.S. Hawkins. 1991. Presence of Bromacil, Diuron, and Simazine in Surface Water Runoff From Agricultural Fields and Non-Crop Sites in Tulare County, California. report PM91-1. Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation.

Lee, M. 1983. Aldicarb contamination of groundwater in Del Norte County. Internal Memo Sep. 21, 1983. PMAP program, California Department of Food and agriculture, Sacramento, CA.

Goolsby, D.A., W.A. Battaglin, and E.M. Thurman. 1993. Occurrence and transport of agricultural chemicals in the Mississippi River basin, July through August 1993. U.S.G.S. Circular 1120-c. 22p.

Pickett, C.H., L.S. Hawkins, J.E. Pehrson, and N.V. O'Connell. 1990. Herbicide use in citrus production and groundwater contamination in Tulare county. California Department of Food and Agriculture, Sacramento, CA 95814.

Spurlock, F., C. Garretson, and J. Troiano. 1997. Runoff from Citrus Orchard Middles: Comparison of Three Herbicides and Effect of Organosilicon Surfactant. Report EH 97-02, EHAP, Calif. Dept. of Pesticide Regulation.

Troiano, ' J., B. Johnson, S. Powell, and S. Schoenig. 1994. Use of cluster and principal component analyses to profile areas in California where ground water has been contaminated by pesticides in California. Environmental Monitoring and Assessment, 32:269-288.

Troiano, J., C. Nordmark, T. Barry, and B. Johnson. 1997. Profiling areas of Ground Water Contamination by Pesticides in California: Phase 11 - Evaluation and Modification of a Statistical Model. Environ. Monitor. Assess. 45:301-318.

Troiano, J. and C. Garretson. 1998. Movement of Simazine in Runoff Water from Citrus Orchard Row Middles as Affected by Mechanical Incorporation. J. Environ. Qual. 27: 488-494.